NEOTROPICAL
BIOLOGY AND CONSERVATION

Neotropical Biology and Conservation
15(4): 415–425 (2020)
doi: 10.3897/neotropical.15.e49656

RESEARCH ARTICLE

Anurofauna of a remnant of Atlantic Forest in northeast Brazil

Gessica Gomes Barbosa[1], Camila Nascimento de Oliveira[1], Umberto Diego Rodrigues de Oliveira[2], Gilberto Gonçalves Rodrigues[1]

1 *Departamento de Zoologia, Universidade Federal de Pernambuco – UFPE, Av. Professor Moraes Rego. CEP 50670-901 – Cidade Universitária, Recife – PE, Brazil*
2 *Instituto de Biologia, Universidade Federal da Bahia – UFBA, Av. Adhemar de Barros. CEP 40170-110, Ondina – Salvador, Brazil*

Corresponding author: Gessica Gomes Barbosa (gessicagomesbarbosa@gmail.com)

Academic editor: A. M. Leal-Zanchet | Received 24 December 2019 | Accepted 2 July 2020 | Published 1 October 2020

Citation: Barbosa GG, de Oliveira CN, de Oliveira UDR, Rodrigues GG (2020) Anurofauna of a remnant of Atlantic Forest in northeast Brazil. Neotropical Biology and Conservation 15(4): 415–425. https://doi.org/10.3897/neotropical.15.e49656

Abstract

Studies on spatial occupation are fundamental to understand amphibian communities. The aim of this study was to record information on the spatial distribution of anurans in the Tejipió forest, state of Pernambuco, northeastern Brazil. Fieldwork was carried out weekly between October 2011 and April 2012, with daytime and night-time excursions for time-constrained active searching, in forested and open areas, military construction area and water bodies. Pitfall traps and accidental sightings were also used as alternative collection methods. Data were used to calculate richness, rarefaction curves and richness estimators. A total of 21 species were recorded, distributed in six families: Bufonidae (2 spp.); Craugastoridae (1 sp.); Hylidae (8 spp.); Leptodactylidae (8 spp.); Microhylidae (1 sp.) and Phyllomedusidae (1 sp.). Only the species *Rhinella jimi* was found occupying all sampled habitats in the research area. *Adenomera hylaedactyla* and *Pristimantis ramagii* deserve special care in the area because they are specialists, occupying a smaller number of habitats and microhabitats. The community of anurans of the Tejipió forest is similar to those recorded in other areas of the Atlantic Forest at the Pernambuco state, and its knowledge is essential as a basis for conservation of the area. The gradual recovery of this Atlantic Forest remnant would favor the recolonization of fauna and flora and the conservation of local biodiversity.

Keywords

abundance, amphibians, conservation, ecology, richness

Copyright *Gessica Gomes Barbosa et al.* This is an open access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

PENSOFT

Introduction

The anurans have a global richness of 8181 known species (Frost 2020), distributed in all continents, except the poles and some oceanic islands. The Neotropical region present one-third of the species known in the world (Duellman 1999). The country that holds the higher diversity of the group is Brazil, with 1137 registered species (Segalla et al. 2019). The Brazilian Atlantic Forest has 625 registered species (Rossa-Feres et al. 2017) and these numbers of species continuously increase with new studies (e.g. Malagoli et al. 2017; Guimarães et al. 2017; Roberto et al. 2017; Walker et al. 2018; Santos et al. 2019).

Originally, the Atlantic Forest biome covered 150 millions of hectares, with heterogeneous environments (Ribeiro et al. 2009). Currently, the biome is highly deforested, characterized by isolated and small fragments. Nonetheless, the Atlantic forest features a high diversity and high levels of endemism, which makes it one biodiversity hotspot (Myers et al. 2000; Ribeiro et al. 2009; Mittermeier et al. 2011). Studies that seek knowledge of ecological aspects of amphibian species serve as conservation initiatives for Atlantic Forest (e.g. Abrahão et al. 2018). Furthermore, studies about biology and distribution of the amphibians make it possible to find out new species, the degree of regional endemism, aside from enriching regional and national scientific collections (Moura et al. 2011). This type of information is very important for the elaboration of effective management and conservation measures (Pereira et al. 2015).

The recovery of vegetation provides peculiar ecological conditions, forming new landscapes and increasing the availability of microhabitats, which might be followed by the recolonization by animals and plants. Studies that aim at evaluating how this process affects biodiversity are, therefore, essential to understand the mechanisms affecting the ecological functioning of areas under regeneration. This paper contributes with the first information about the local anurans community we recorded information on the spatial distribution of anurans in the Tejipió forest, an area under regeneration at the state of Pernambuco, northeastern Brazil.

Methods

Study site

The study was conducted in the Tejipió forest (08°05'45,59"S, 34°57'04,91"W) (Fig. 1), a set of discontinued forest fragments at BR-101 Sul, in the Recife metropolitan area, state of Pernambuco, Brazil. The forest was donated by the Ministry of Agriculture to the Fourth Communications Battalion of the Brazilian army (4°BCom). The Tejipió forest occupies 172 hectares, consisting of an Atlantic Ombrophilous Dense Forest. The climate is characterized as As' according to Köppen (Silva et al. 2014). The mean annual temperature is 25.4 °C and mean annual rainfall is 2.458 mm (World Weather Information Service 2013), with rains occurring between the months of January and August (APAC 2020). The site is located within the Tejipió river hydrographic basin (Araújo and Pires 1998).

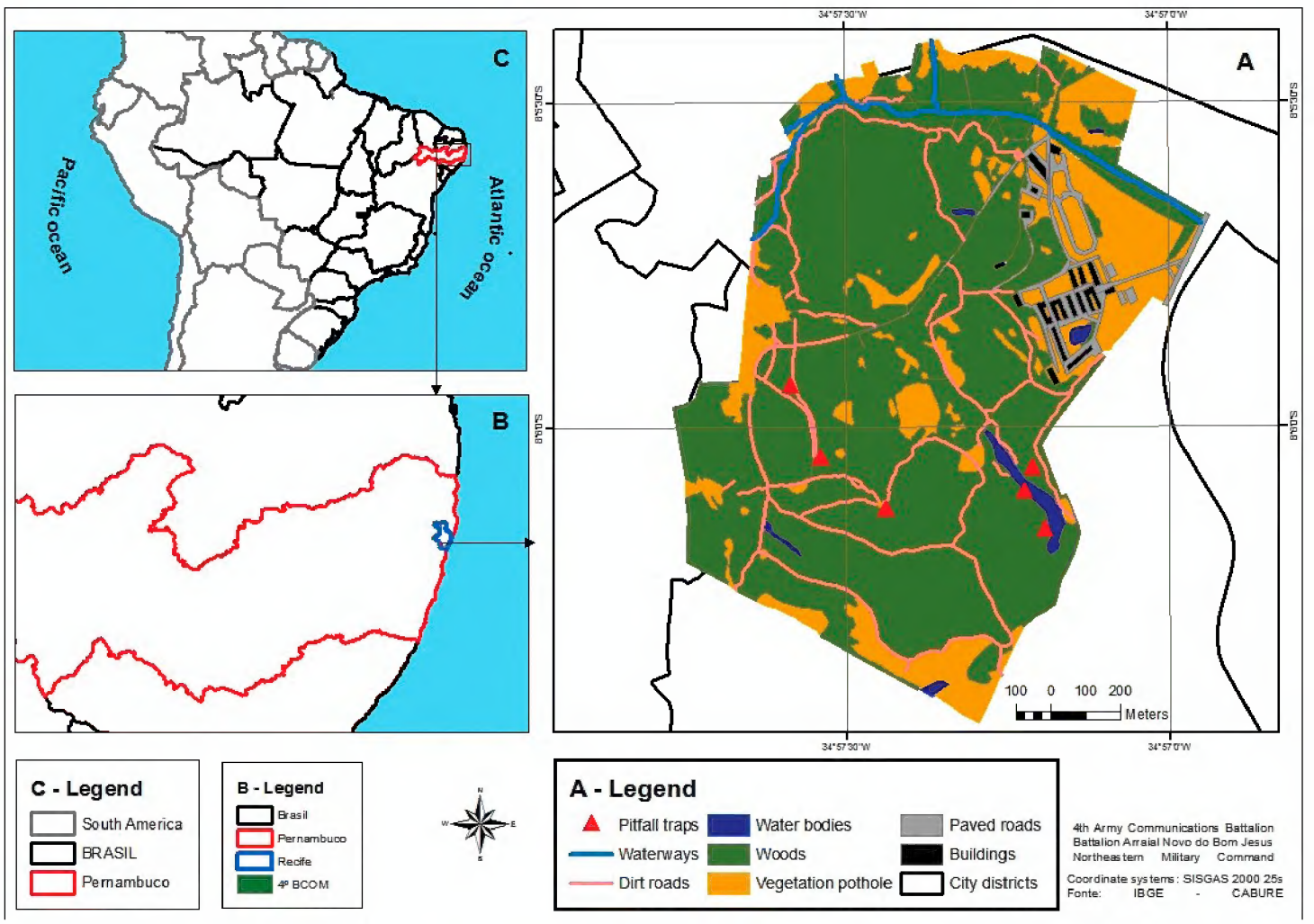

Figure 1. Location of the study site (Tejipió forest), Recife, Pernambuco, northeastern Brazil. The red triangles show the location of the pitfall traps.

These fragments present low arboreal heterogeneity (Feitosa 2004), with its vegetation in progressive restoration (Guimarães et al. 2012), a process that began 50 years ago. The study site contains a forested area with a lentic water body (lake), surrounded by human communities and a military construction, with another smaller lake nearby.

Sampling

Our sampling was carried out weekly between October 2011 and April 2012 using pitfall traps, time-constrained active searches and accidental sightings. Active searches were carried out for nine hours per day, with diurnal and nocturnal searches, and totalized a sampling effort of 252 man-hours. We selected different habitats with contrasting characteristics: habitat I – open area, lightly wooded dry sites surrounded by forest; habitat II – forest area, "a minimum area of land of 0.05–1.0 hectares with tree crown cover (or equivalent stocking level) of more than 10–30 % with trees with the potential to reach a minimum height of 2–5 meter at maturity in situ", according to Kyoto Protocol (Kant 2006); habitat III – permanent water bodies, lake 1 (8°6'35.99"S, 34°57'12.04"W), occupying 6.943 m^2 surrounded by forest and lake 2, (8°5'50.03"S, 34°57'6.68"W), occupying 2.886 m^2 surrounded by military construction. Both have emergent and free floating aquatic weeds; habitat IV – small

temporary water bodies, occupying less than 10 m^2 and dry during the dry season; and habitat V – military construction area, in the vicinity of the human habitation. In addition, we selected nine different microhabitats: 1) leaf litter (dead plant material that have fallen to the ground); 2) bare ground (soil without vegetation cover); 3) humid soil (soil with water retention); 4) buildings (e. g. walls, rooms, bathroom, among other things); 5) emergent aquatic weeds (plants that are rooted in the water body bottom, extending above the surface of the water); 6) free floating aquatic weeds (plants living on the water's surface); 7) shrubs (small to medium sized woody plants); 8) partially immersed in water; and 9) buried in the ground (basically a hole used as a dwelling).

The pitfall traps were installed at six samplings station. Each station had four buckets, two with 60 L capacity and two with 22 L capacity, intercalated. The buckets were arranged linearly and connected by 10 m of plastic drift fences, with two plastic drift fences at the ends of the traps, totalizing 50 m. The sampling effort totalized 16,128 hours of trapping.

The specimens caught were identified and released (collecting authorization no. 31795-1 of the Chico Mendes Institute for Biodiversity Conservation). Furthermore, specimens found dead were deposited in the Herpetology Collection of the Federal Rural University of Pernambuco (CHP-UFRPE).

Data analyses

To evaluate the sampling effect, we constructed a rarefaction curve. Species richness was calculated through the richness estimators Chao 1, Jackknife 1 and Bootstrap, using 1000 random additions of the samples. The analyses were performed using EstimateS software, version 9.1 (Colwell 2013).

Results

We registered 1106 specimens, belonging to 21 species, 10 genera and 6 families: Bufonidae (2 spp.); Craugastoridae (1 sp.); Hylidae (8 spp.); Leptodactylidae (8 spp.); Microhylidae (1 sp.) and Phyllomedusidae (1 sp.) (Table 1). The Hylidae and Leptodactylidae families presented the higher richness, both with eight species each (38,1 %). The species of the family Hylidae that presented greatest specimen abundance were *Dendropsophus branneri* (231 individuals), *Dendropsophus decipiens* (63 individuals) and *Scinax nebulosus* (38 individuals). In turn, *Adenomera hylaedactyla* (273 individuals), *Leptodactylus natalensis* (61 individuals) and *Leptodactylus macrosternum* (46 individuals) showed greatest specimen abundance among Leptodactylidae species.

The rarefaction curve (Fig. 2) presented a strong tendency towards stability from the 10th sample, indicating approximation to real number of species; in other words, the methods and effort used were efficient in sampling the area. The richness estima-

Table 1. Composition and abundance of the anuran species registered during the months of October of 2011 to April 2012 in the Tejipió forest, northeastern Brazil. Habitats: I. Open area, II. Forest area, III. Permanent water bodies, IV. Temporary water bodies and V. Military construction area. Microhabitats: 1. Leaf litter, 2. Bare ground, 3. Humid soil, 4. Buildings, 5. Emergent aquatic weeds, 6. Free floating aquatic weeds, 7. Shrubs, 8. Partially immersed in water and 9. Buried in the ground. Form of register (FR): a) Pitfall traps, b) Time-constrained active searching, and c) Accidental sightings.

Taxon	Habitat	Microhabitat	FR	Abundance
Family Bufonidae				
Rhinella granulosa (Spix, 1824)	I	3	c	1
Rhinella jimi (Stevaux, 2002)	I, II, III, IV, V	1, 2, 3, 4	a, b	24
Family Craugastoridae				
Pristimantis ramagii (Boulenger, 1888)	II	1	a, b	172
Family Hylidae				
Boana albomarginata (Spix, 1824)	III, IV	5, 7	b	33
Boana raniceps (Cope, 1862)	III, IV	5, 7	b	5
Dendropsophus branneri (Cochran, 1948)	III, IV	5, 6, 8	b	231
Dendropsophus decipiens (Lutz, 1925)	III, IV	5, 6, 8	b	63
Dendropsophus elegans (Wied-Neuwied, 1824)	III, IV	5	b	3
Dendropsophus minutus (Peters, 1872)	III, IV	5, 6, 8	b	14
Scinax nebulosus (Spix, 1824)	III, IV	5, 6	b	38
Scinax x-signatus (Spix, 1824)	III, IV	5, 6	b	24
Family Leptodactylidae				
Adenomera hylaedactyla (Cope, 1868)	II	1, 2	a, b	273
Leptodactylus fuscus (Schneider, 1799)	I, III	3	a, b	14
Leptodactylus macrosternum Miranda-Ribeiro, 1926	III	3, 8	b	46
Leptodactylus mystaceus (Spix, 1824)	II	-	a	1
Leptodactylus natalensis Lutz, 1930	III	3	a, b	61
Leptodactylus troglodytes Lutz, 1926	I	2	a, b	9
Leptodactylus vastus Lutz, 1930	II, III, IV	1, 2, 3, 8	a, b	24
Physalaemus cuvieri Fitzinger, 1826	I, II, IV	1, 2, 3, 8	a, b	43
Family Microhylidae				
Elachistocleis cesarii (Miranda-Ribeiro, 1920)	II	1, 9	a, b	4
Family Phyllomedusidae				
Pithecopus nordestinus (Caramaschi, 2006)	III	5	b	23

tors Chao 1, Jackknife 1 and Bootstrap estimated a richness of 22, 23 and 22 species, respectively, with values of richness very close to the observed richness (Fig. 3).

The time-constrained active searching method was more successful at finding different species (19 spp.) compared to the pitfall traps method (10 spp.) and accidental sightings (1 sp.) (Table 1). Only the species *Leptodactylus mystaceus* was recorded exclusively through the pitfall method, and *Rhinella granulosa* was recorded through accidental sightings, during a heavy rain event.

The highest number of species was associated with permanent water bodies (lakes) and temporary water bodies (Table 1). The hylids were recorded in association with water bodies (habitats III and IV). While leptodactylids were recorded occupying four habitats (habitats I, II, III and IV), with the species *L. vastus* and *P. cuvieri* recorded in a greater number of habitats. We recorded two species of the

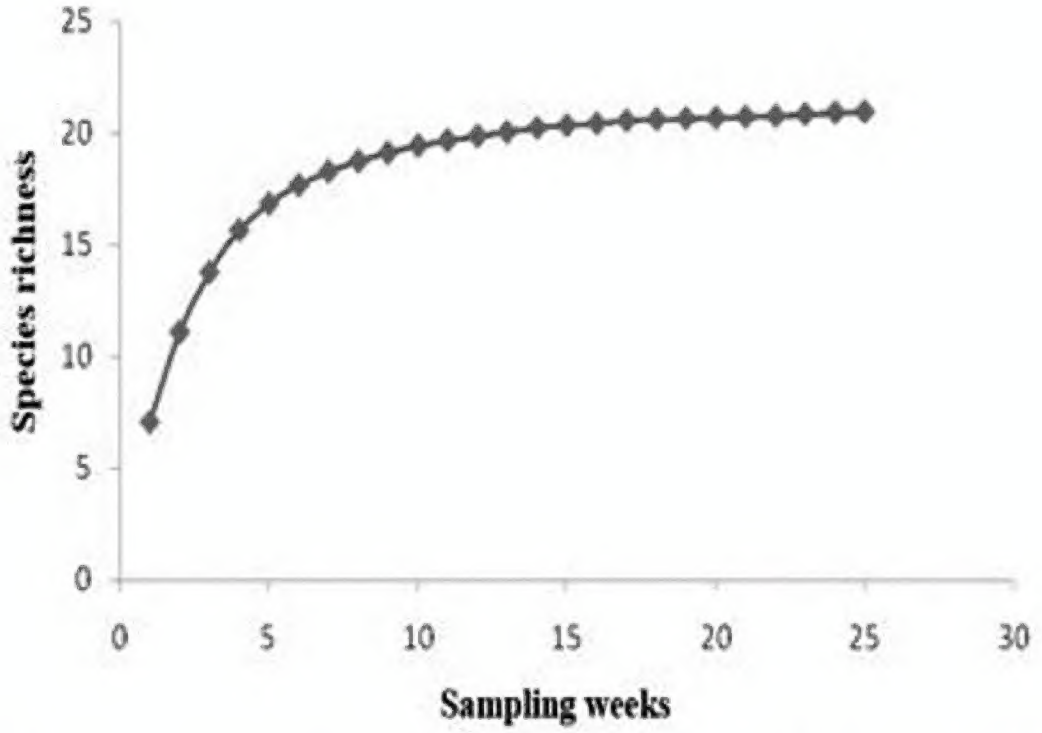

Figure 2. Rarefaction curve representing the accumulated richness of the species of anurans in the Tejipió forest, northeastern Brazil, recorded between October 2011 and April 2012.

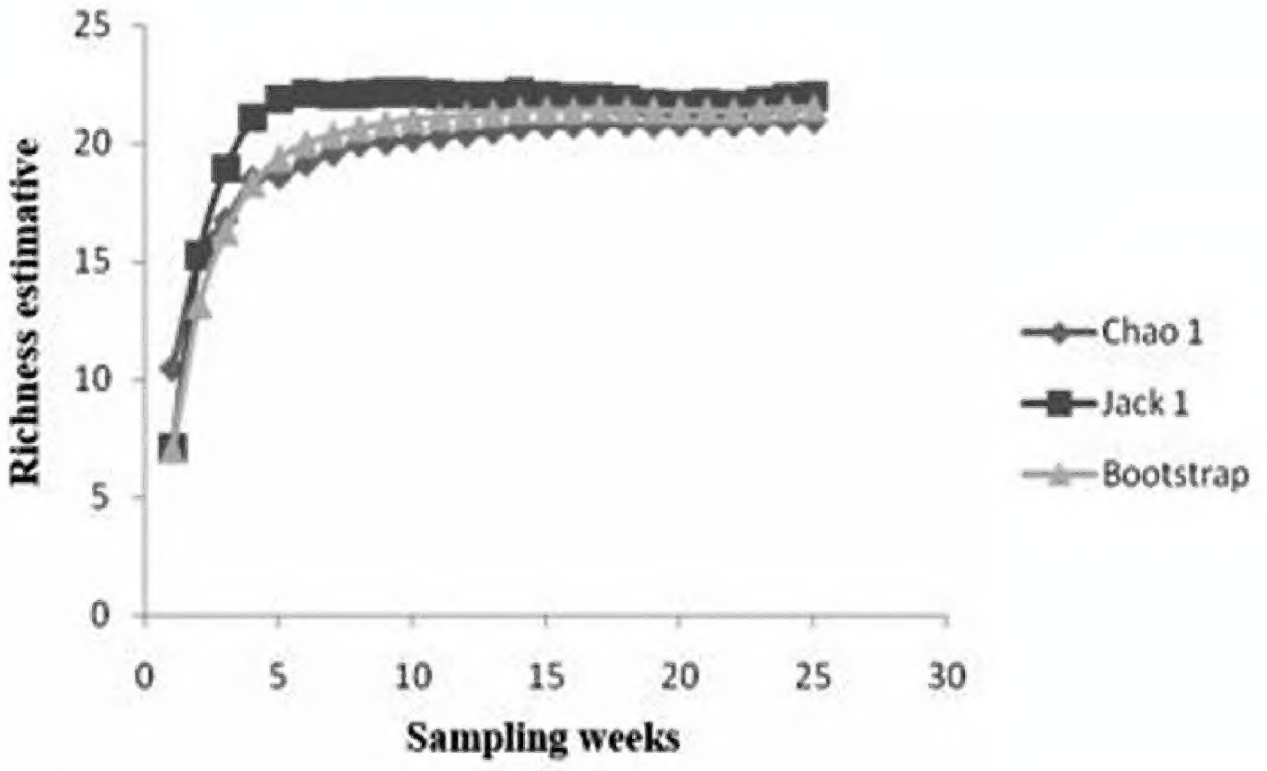

Figure 3. Richness estimators based on the abundance of anurans species recorded in the Tejipió forest, northeastern Brazil, between October 2011 and April 2012.

family Bufonidae, *R. jimi* and *R. granulosa.* Only the species *Rhinella jimi* was recorded occupying all the sampled habitats.

The microhabitats shared by highest number of species were the emergent aquatic weeds (*B. albomarginata*, *B. raniceps*, *D. branneri*, *D. decipiens*, *D. elegans*, *D. minutus*, *S. nebulosus*, *S. x-signatus* and *P. nordestinus*), humid soil (*R. granulosa*, *R. jimi*, *L. fuscus*, *L. macrosternum*, *L. natalensis*, *L. vastus* and *P. cuvieri*), leaf litter (*R. jimi*, *P. ramagii*, *A. hylaedactyla*, *L. vastus*, *P. cuvieri* and *E. cesarii*) and partially

immersed in water (*D. branneri*, *D. decipiens*, *D. minutus*, *L. macrosternum*, *L. vastus* and *P. cuvieri*) (Table 1). *Leptodactylus vastus*, *P. cuvieri* and *R. jimi* used the greatest number of microenvironments, with four microhabitats each. The species *L. natalensis*, *L. troglodytes*, *P. nordestinus*, *P. ramagii* and *R. granulosa* were recorded only in one habitat and microhabitat.

Discussion

The 21 sampled species of anurans correspond to 24.1 % of the total species known to occur in the state of Pernambuco (Semas 2015). Atlantic Rainforest remnants in northeastern Brazil present an equal or a smaller number of species than we found in our study, such as State Park Ecotourism and Sustainable Development of Cachoeira do Urubu (21 spp.) (Barbosa et al. 2019) and Mata do Buraquinho (14 spp.) (Santana et al. 2008). Nevertheless, there are fragments with higher anuran richness, such as the integral protection area Wildlife Refuge Matas do Sistema Gurjaú (Pernambuco) with 30 spp. (Barbosa et al. 2018) and Cariri Farm (Alagoas) with 32 spp. (Palmeira and Gonçalves 2015). The species recorded are not listed as threatened (MMA 2014; Semas 2015; ICMBio 2016; IUCN 2020). The families with greatest richness were Hylidae and Leptodactylidae, which show high diversity in the Atlantic Forest (Rossa-Feres et al. 2017) and in Brazil (Segalla et al. 2019), a pattern also found in the whole Neotropical region (Duellman and Trueb 1994; IUCN 2020).

Regarding the three species registered with higher abundance in this study, *A. hylaedactyla*, *D. branneri* and *P. ramagii* are widely distributed in Brazil. The first *A. hylaedactyla* is widespread, occurring in Amazonia, Chaco, Cerrado, Caatinga and Atlantic Forest (Fouquet et al. 2013). Our study area has diverse environments for *A. hylaedactyla*, where this species generally is omnipresent, being abundant in leaf litter, according to Borges-Leite et al. (2015). In addition, pitfall traps are efficient in collecting these organisms with terricolous habits. The species *D. branneri* has a broad geographic distribution along the Brazilian coast (Haddad et al. 2013; Frost 2020), being an endemic species of the Atlantic Forest (Rossa-Feres et al. 2017). This species is found in temporary and permanent lakes (Juncá 2006; Palmeira and Gonçalves 2015) and has been registered in large groups producing advertisement calls. *Pristimantis ramagii* belongs to a genus comprised by typical frogs of forested areas (Pinto-Sánchez et al. 2012) and native to South America (Hedges et al. 2008). The species *P. ramagii* is distributed from the state of Paraíba to the north of Bahia (Haddad et al. 2013; Frost 2020) and considered an endemic species of the Atlantic Forest (Rossa-Feres et al. 2017), being exclusively found on forested areas in the present study.

The composition of the anuran assembly can vary according to local factors, environmental heterogeneity (Huston 1994), anthropic impacts (Young et al. 2001) and species phenology. Besides, anurans area generally affected by the rainfall distribution, due to an increased number of aquatic sites available for reproduction (Duellman and Trueb 1994). In the environments with anthropic alterations and high solar radiation, we found only individuals of the Bufonidae family. This can be

explained because the individuals of the genus *Rhinella* present a higher tolerance to water loss compared to other anurans (Thorson 1955). *Rhinella jimi*, for example, is very generalist, occurring in secondary forest, savannah, agricultural lands, other open areas and disturbed habitats (Gilda and Carnaval 2004), being also generalist in our study. Another example, *R. granulosa*, is tolerant to high temperatures (Oliveira and Cassemiro 2013), we recorded a specimen in an open area.

Regarding the families that presented higher occupancy of microhabitats (Bufonidae, Hylidae and Leptodactylidae), the Bufonidae species recorded in our study are terrestrial. They were recorded in herbaceous vegetation and humid soil (Barbosa and Alves 2014). Hylidae family is recorded occupying arboreal habits, adding the possibility of vertical movement (Cardoso et al. 1989), in this case occupying shrubs, due the presence of hand adhesive discs allows them to occupy more diverse environments. The family Leptodactylidae comprises generalist organisms, which only need bodies of water to reproduce (Coelho and Oliveira 2010). These organisms occupy temporary aquatic ecosystems in open areas (Feio and Ferreira 2005), being found in the soil, margins of dams and flooded areas (Amorim et al. 2009). However, in the Tejipió forest leptodactylid species mainly occupied permanent water bodies and forest areas.

The species *P. ramagii* occupies forested areas under the leaf litter, which highlights the importance of conservation of forest areas for the species. However, Santana et al. (2008) observed *P. ramagii* occupying a variety of microhabitats, such as humid soils, leaf litter, shrubs and fallen trunks. *Adenomera hylaedactyla*, *E. cesarii* and *L. mystaceus* also occupying only forest areas, these highlights importance of conservation of forest areas. Despite the great abundance, *P. ramagii* and *A. hylaedactyla* were recorded in only one habitat (forest area) and few microhabitats (one and two microhabitats, respectively), indicating environmental specificity.

It is important to mention the high biological relevance of the studied area, because this highlights its scientific potential. Future studies are essential to assess how the recolonization of anurans is associated with local forest regeneration. During the study, countless impacts caused by people entering in the forest were observed, such as fire, trash release, removing soil and deforestation, among others. Thus, the presence of the Military Brigade in the area is important for its conservation (Guimarães et al. 2012), maintaining the local biodiversity. The present study aids as a first step towards the knowledge of the anuran fauna of the area, aiming to create ecological projects and public policies to preserve the area at a medium and long run.

References

Abrahão CR, Moura GJB, Freitas MA, Escarlate-Tavares F (2018) Plano de ação nacional para a conservação da herpetofauna insular ameaçada de extinção. Instituto Chico Mendes de Conservação da Biodiversidade, ICMBio, Brasília, 253 pp.

Amorim FO, Schmaltz-Peixoto KEV, Araújo LCSS, Santos EM (2009) Temporada e turno de vocalização de *Leptodactylus natalensis* Lutz, 1930 (Amphibia, Anura) na Mata Atlân-

tica de Pernambuco, Brasil. Revista Papéis Avulsos de Zoologia 49(1): 1–7. https://doi.org/10.1590/S0031-10492009000100001

APAC (2020) [Agência Pernambucana de águas e climas] http://www.apac.pe.gov.br/

Araújo AM, Pires TT (1998) Simulação exploratória dos efeitos das marés na circulação e transporte hidrodinâmicos da Bacia do Pina. Revista Brasileira de Recursos Hídricos 3(3): 57–71. https://doi.org/10.21168/rbrh.v3n3.p57-71

Barbosa GG, de Oliveira UDR, Laurindo TS, Rodrigues GG (2018) Anfíbios de uma área protegida de Mata Atlântica, nordeste do Brasil. In: Braz ECF, de Amorim FJ (Eds) Pesquisas científicas e práticas de educação ambiental no Refúgio de Vida Silvestre Matas do Sistema Gurjaú. CPRH – Recife, Liceu, 33 pp.

Barbosa VN, Amaral JMS, Nino KS, Lima LFL, dos Santos IYGS, de Albuquerque GVL, dos Santos EM (2019) Herpetofauna do Parque Estadual Ecoturístico e de Desenvolvimento Sustentável da Cachoeira do Urubu, Primavera, Pernambuco, Brasil. Cadernos de Pesquisas 31: 31–45. https://doi.org/10.17058/cp.v31i1.12273

Borges-Leite MJ, Rodrigues JF, Gondim PM, Borges-Nojosa DM (2015) Reproductive activity of *Adenomera* aff. *hylaedactyla* (Anura: Leptodactylidae) in a coastal area of Brazil. Animal Biology (Leiden, Netherlands) 65(2): 101–111. https://doi.org/10.1163/15707563-00002464

Cardoso AJ, Andrade GV, Haddad CFB (1989) Distribuição espacial das comunidades de anfíbios (Anura) no Sudeste do Brasil. Ver. Brasl. Biol. 49: 241–249.

Coelho HEDA, Oliveira RS (2010) Anurofauna de um fragmento de Mata Atlântica em Lauro de Freitas-Bahia. Candombá Revista Virtual 6: 52–60.

Colwell RK (2013) EstimateS, Version 9.1: Statistical Estimation of Species Richness and Shared Species from Samples.

Duellman WE (1999) Patterns of distribution of amphibians. Johns Hopkìns Univ. Press, Baltimore.

Duellman WE, Trueb L (1994) Biology of Amphibians. The Johns Hopkins University Press, New York, 670 pp.

Feio RN, Ferreira PL (2005) Anfíbios de dois fragmentos de Mata Atlântica no município de Rio Novo, Minas Gerais. Revista Brasileira de Zoociências 7: 121–128.

Feitosa AAN (2004) Diversidade de espécies florestais arbóreas associada ao solo em toposseqüência de fragmento de Mata Atlântica de Pernambuco, Brasil. Mestrado em Ciências do Solo. Universidade Federal de Pernambuco.

Fouquet A, Cassini CS, Haddad CFB (2013) Species delimitation, patterns of diversification and historical biogeography of the Neotropical frog genus *Adenomera* (Anura, Leptodactylidae). Journal of Biogeography 41(5): 855–870. https://doi.org/10.1111/jbi.12250

Frost DR (2020). Amphibian Species of the World: an Online Reference, version 6.1. https://amphibiansoftheworld.amnh.org/index.php

Gilda A, Carnaval AC (2004) *Rhinella jimi*. The IUCN Red List of Threatened Species 2004. http://www.iucnredlist.org/details/54674/0 [acessed: October 2 2018]

Guimarães HDB, Braga RA, de Oliveira TH (2012) Evolução da condição ambiental em fragmentos de Mata Atlântica na Região Metropolitana do Recife – PE. Agrária 7(2): 306–314. https://doi.org/10.5039/agraria.v7i2a1439

Guimarães CS, Luz S, Rocha PC, Feio RN (2017) The dark side of pumpkin toadlet: a new species of *Brachycephalus* (Anura: Brachycephalidae) from Serra do Brigadeiro, south-eastern Brazil. Zootaxa 4258(4): 327–344. https://doi.org/10.11646/zootaxa.4258.4.2

Haddad CFB, Toledo LF, Prado CPA, Loebman D, Gasparini JL, Sazima I (2013) Anfíbios da Mata Atlântica: Guia dos anfíbios anuros da Mata Atlântica. Editora Neotropica, São Paulo, 544 pp.

Hedges SB, Duellman WE, Heinicke MP (2008) New World direct-developing frogs (Anura: Terrarana): molecular phylogeny, classification, biogeography, and conservation. Zootaxa 1737(1): 1–182. https://doi.org/10.11646/zootaxa.1737.1.1

Huston MA (1994) Biological diversity – The coexistence of species on changing landscapes. 19th ed. Cambridge University Press, New York, USA, 681 pp.

ICMBio [Instituto Chico Mendes de Conservação da Biodiversidade] (2016) Livro Vermelho da Fauna Brasileira ameaçada de extinção, Brasília/DF, 76 pp.

IUCN (2020) Red list of threatened species. http://www.iucnredlist.org

Juncá FA (2006) Diversidade e uso de hábitat por anfíbios anuros em duas localidades de Mata Atlântica, no norte do estado da Bahia. Biota Neotropica 6(2): 1–17. https://doi.org/10.1590/S1676-06032006000200018

Kant P (2006) Definition of forest under Kyoto Protocol; choosing appropriate values for crown cover, area and tree height for India. Indian Forester 132(5): 632.

Malagoli LR, de Sá FP, Canedo C, Haddad CF (2017) A New Species of *Hylodes* (Anura, Hylodidae) from Serra do Mar, Southeastern Brazil: The Fourth with Nuptial Thumb Tubercles. Herpetologica 73(2): 136–147. https://doi.org/10.1655/HERPETOLOGICA-D-16-00069

Mittermeier RA, Turner WR, Larsen FW, Brooks TM, Gascon C (2011) Global biodiversity conservation: the critical role of hotspots. In: Frank E, Zachos JCH (Eds) Biodiversity hotspots. Springer, Berlin/Heidelberg, 3–22. https://doi.org/10.1007/978-3-642-20992-5_1

MMA [Ministério do Meio Ambiente] (2014) Lista nacional oficial de espécies de fauna ameaçadas de extinção. Diário Oficial, 14 dezembro de 2014. http://www.icmbio.gov.br/portal/biodiversidade/fauna-brasileira/lista-de-especies.html

Moura GJB, Santos EM, Andrade EVE, Freire EMX (2011) Distribuição geográfica e caracterização ecológicas dos anfíbios do estado de Pernambuco. In: Moura GJB, dos Santos EM, Oliveira MAB, Cabral ACC (Eds) Herpetologia do Estado de Pernambuco 1ª ed. Ministério do Meio Ambiente, Brasília, 51–84.

Myers N, Mittermeier RA, Mittermeier CG, da Fonseca GA, Kent J (2000) Biodiversity hotspots for conservation priorities. Nature 403(6772): 853–858. https://doi.org/10.1038/35002501

Oliveira HR, Cassemiro FAS (2013) Potenciais efeitos das mudanças climáticas futuras sobre a distribuiçãode um anuro da Caatinga *Rhinella granulosa* (Anura, Bufonidae). Iheringia. Série Zoologia 103(3): 272–279. https://doi.org/10.1590/S0073-47212013000300010

Palmeira CNS, Gonçalves U (2015) Anurofauna de uma localidade na parte septentrional da Mata Atlântica, Alagoas, Brasil. Boletim do Museu de Biologia Mello Leitão, 37.

Pereira EN, Teles MJL, Santos EM (2015) Herpetofauna em remanescente de Caatinga no Sertão de Pernambuco, Brasil. Boletim do Museu de Biologia Mello Leitão 37(1): 29–43.

Pinto-Sánchez NR, Ibáñez R, Madriñán S, Sanjur OI, Bermingham E, Crawford AJ (2012) The great American biotic interchange in frogs: multiple and early colonization of Central America by the South American genus *Pristimantis* (Anura: Craugastoridae). Molecular Phylogenetics and Evolution 62(3): 954–972. https://doi.org/10.1016/j.ympev.2011.11.022

Ribeiro MC, Metzger JP, Martensen AC, Ponzoni FJ, Hirota MM (2009) The Brazilian Atlantic Forest: How much is left, and how is the remaining forest distributed? Implications for conservation. Biological Conservation 142(6): 1141–1153. https://doi.org/10.1016/j.biocon.2009.02.021

Roberto IJ, Araujo-Vieira K, de Carvalho-e-Silva SP, Ávila RW (2017) A New Species of *Sphaenorhynchus* (Anura: Hylidae) from Northeastern Brazil. Herpetologica 73(2): 148–161. https://doi.org/10.1655/HERPETOLOGICA-D-16-00021

Rossa-Feres DC, Garey MV, Caramaschi U, Napoli MF, Nomura F, Bispo A, Brasileiro CA, Thome MTC, Sawaya RJ, Conte CE, Cruz CA, Nascimento LB, Gasparini JL, Almeida NP, Haddad CFB (2017) Anfíbios da Mata Atlântica: lista de espécies, histórico dos estudos, biologia e conservação. In: Monteiro-Filho ELA, Conte CE (Eds) Revisões em Zoologia: Mata Atlântica. Editora UFPR, Curitiba, 237–314.

Santana GG, Vieira WL, Pereira-Filho GA, Delfim FR, Lima YC, Vieira KS (2008) Herpetofauna em um fragmento de Floresta Atlântica no estado da Paraíba, Região Nordeste do Brasil. Biotemas 21(1): 75–84. https://doi.org/10.5007/2175-7925.2008v21n1p75

Santos MTT, de Oliveira SH, de Carvalho TR, Zaidan BF, da Silva NR, Berneck BVM, Garcia PCA (2019) A new species *Paratelmatobius* (Anura: Leptodactylidae: Paratelmatobiinae) from the Atlantic Forest of southern Brazil. Zootaxa 4648(3): 473–479. https://doi.org/10.11646/zootaxa.4648.3.4

Segalla MV, Caramaschi U, Cruz CAG, Garcia PCA, Grantt T, Haddad CFB, Santana DJ, Toledo LF, Langone JA (2019) Brazilian amphibians: List of species. Herpetologia Brasileira 8: 65–96.

Semas [Secretária de meio ambiente e sustentabilidade] (2015) Lista estadual oficial de espécies da fauna ameaçada de extinção – Anfíbios. Diário Oficial do Estado de Pernambuco, 27 January 2015. http://www.cepe.com.br

Silva AO, Moura GBA, Klar AE (2014) Classificação climática de Thornthwaite e sua aplicabilidade agroclimatológica nos diferentes regimes de precipitação em Pernambuco. Irriga 19(1): 46–60. https://doi.org/10.15809/irriga.2014v19n1p46

Thorson TB (1955) The relationship of water economy to terrestrialism in amphibians. Ecology 36(1): 100–115. https://doi.org/10.2307/1931435

Walker M, Wachlevski M, Nogueira-Costa P, Garcia PCA, Haddad CFB (2018) A new species of *Fritziana* Mello-Leitão 1937 (Amphibia: Anura: Hemiphractidae) from the Atlantic Forest, Brazil. Herpetologica 74(4): 329–341. https://doi.org/10.1655/HERPETOLOGICA-D-17-00068.1

World Weather Information Service (2013) Climatological Information. https://worldweather.wmo.int

Young BE, Lips KR, Reaser JK, Ibáñez R, Salas AW, Cedeño JR, Romo D (2001) Population declines and priorities for amphibian conservation in Latin America. Conservation Biology 15(5): 1213–1223. https://doi.org/10.1046/j.1523-1739.2001.00218.x